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F2R RD
U1S S1834 S1839 S1840 S1848 S1987 S1999

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(58) Field of Search
UK CL (Edition T) **B7W WWJB , F1V VCVV , F2R RD**
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(54) Abstract Title
AEROFOIL WITH PROTRUDING AERODYNAMIC SURFACE

(57) An aerodynamic device comprising an aerofoil 1 having a leading 2 and trailing 3 edge and one or more protruding 4 aerodynamic surfaces positioned upon the fluid accelerating surface. The protrusions which have a symmetrical shape about the chordal line of the aerofoil 1 are characterised by a convex arcuate portion 5 towards the leading edge and a flatter tail portion 6 towards the trailing edge.

The protrusions 4 may have a surface 7 parallel to the fluid accelerating surface, a height consistent with the fluid boundary layer, a maximum width at the arcuate portion located about one third from the vertex nearest the leading edge 2, and be variable in chord length.

The protrusions may be fixed or movable, and may extend/retract into the fluid stream in combination with flaps or slats. Protrusions 4 may be equi-spaced along the span of the aerofoil and at the aerofoil ends.

The aerofoil may have an angle of attack greater than 13 degrees, and may be used on aircraft, propeller, windmill, watermill, helicopter, boat, or turbine applications.

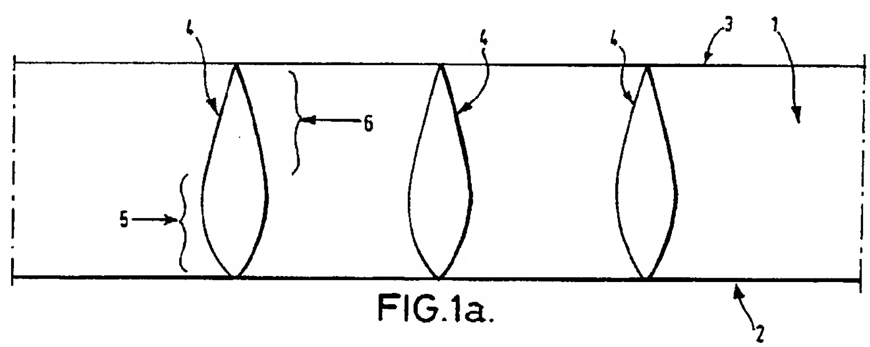

FIG.1a.

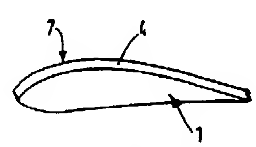

FIG.1b.

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

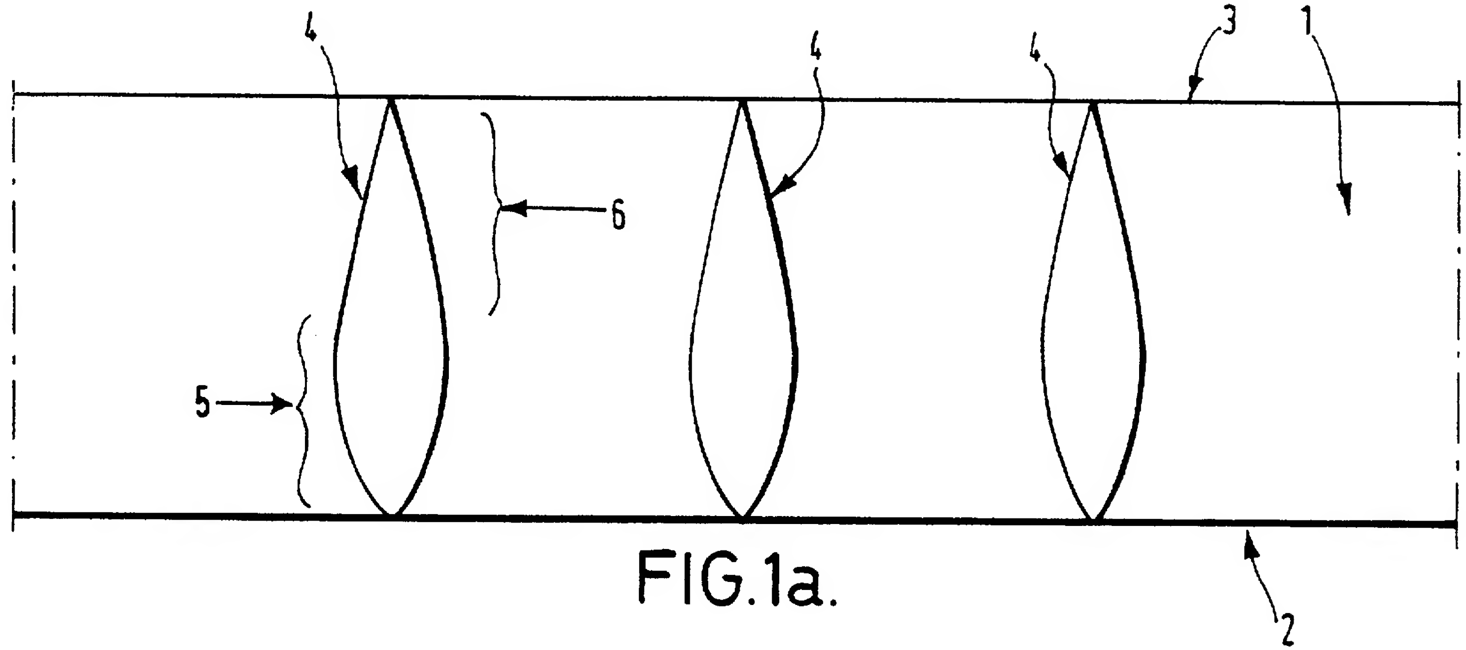

FIG.1a.

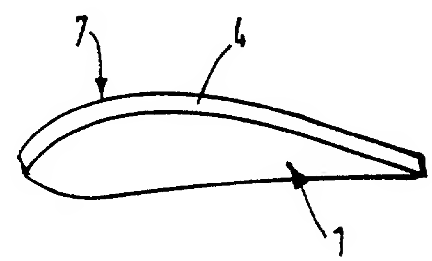

FIG.1b.

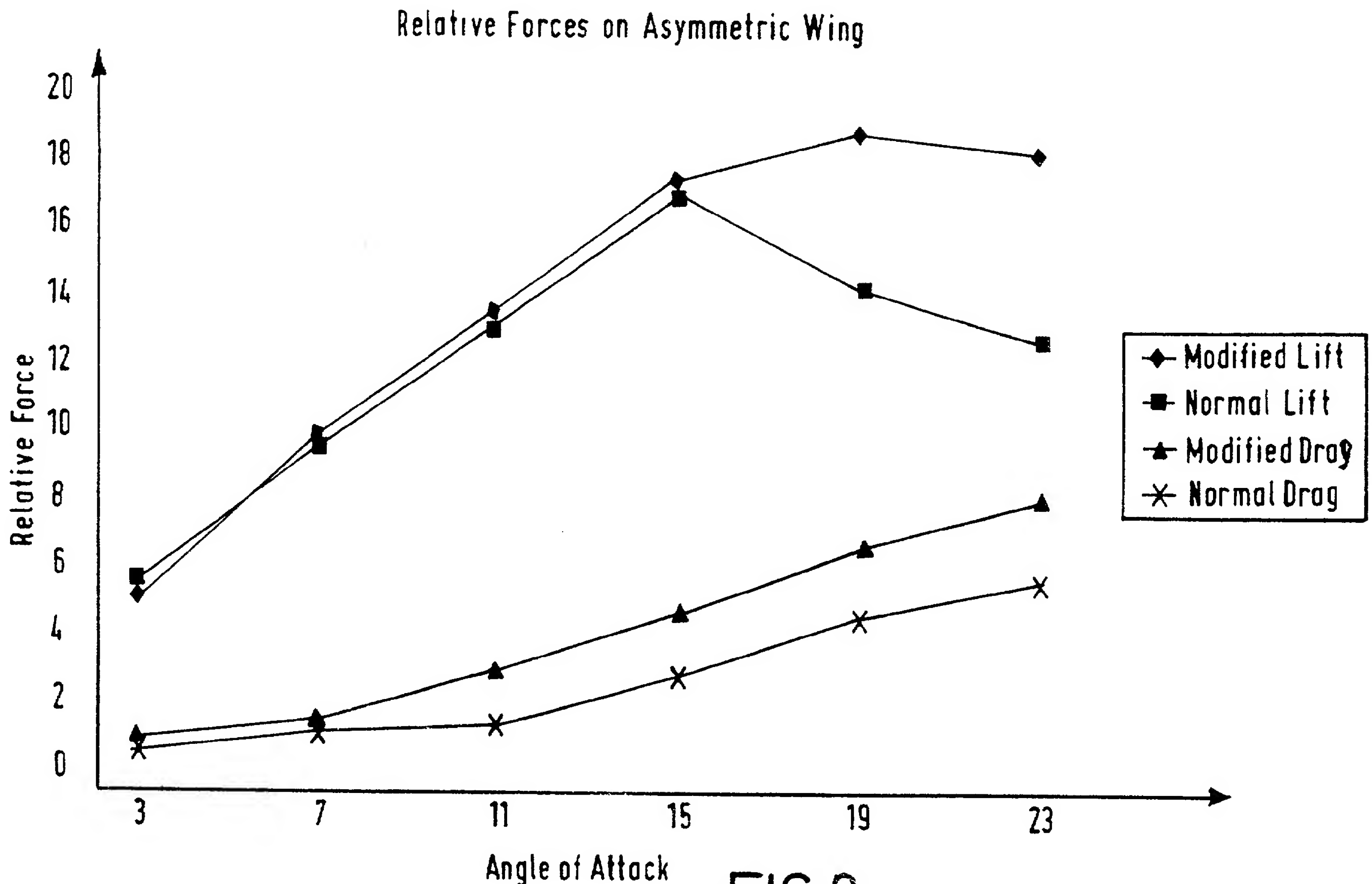
Relative Forces on Asymmetric Wing
Relative Force
20
18
16
14
12
10
8
6
4
2
0
3
7
11
15
19
23
Angle of Attack
Modified Lift
Normal Lift
Modified Drag
Normal Drag

FIG.2.

MULTI-DIMENSIONAL AERODYNAMIC DEVICE

This invention relates to a multi-dimensional aerodynamic device for improving the efficiency and performance of a wing, propeller or the like in a variety of aerodynamic applications.

The basic aerodynamic shape of an aerofoil is well known and is commonly used in aircraft wings, propellers (for aircraft or waterborne vehicles) and the like to provide lifting or propulsion of a body moving in a fluid medium. Such shapes are also used to permit vehicles such as boats and cars to travel forwards in a fluid medium at speed with minimal drag. It is well known from Bernoulli's principle that fluid passing over the convex surface of an aerofoil speeds up creating a consequent reduction in pressure relative to fluid travelling more slowly past a flatter surface of the aerofoil, or without being obstructed by the aerofoil. This results in a force tending to move the aerofoil from the higher pressure fluid towards the lower pressure fluid. In an aircraft wing, for example, the convex surface of the aerofoil would be carried on the upper surface of the wing and the wing would tend to move upwards carrying the aircraft into flight. It is to be understood that the convex surface may be suitably positioned to cause motion in directions other than up.

Another factor of importance in securing lift in an aerofoil is the angle of attack. This is the angle of the aerofoil to the direction of motion. By angling the aerofoil to the direction of fluid flow, the front face of the aerofoil is made to push the surrounding fluid, causing a reactive force having a component in the direction of desired lift. The angle of attack is generally selected for a particular aerofoil application to be more effective in maintaining a desired lift than is provided by the aerofoil's Bernoulli effect. For a standard aerofoil aircraft wing the optimum angle of attack for take off has been found to be around 11 to 13°. At higher angles of attack chaotic turbulence occurs to the rear of the aerofoil creating drag and inhibiting smooth motion of the aerofoil through the fluid.

The present invention aims to provide an aerodynamic device based on an aerofoil, the device having improved lift and reduced chaotic turbulence at higher angles of attack.

In accordance with the present invention, there is provided an aerodynamic device comprising an aerofoil having a first fluid accelerating surface and an opposing second surface, a leading edge facing the direction of motion of the aerofoil and a trailing edge opposing the leading edge, the first fluid accelerating surface having positioned thereon one or more protruding pieces, the pieces being characterised by a shape comprising, two opposing substantially symmetrical portions adjoined at two vertices about a line of symmetry extending between the vertices and chord-wise of the aerofoil, each symmetrical portion comprising a substantially convex arcuate portion towards the leading edge of the aerofoil and an extending, flatter tail portion towards the trailing edge of the aerofoil.

It is to be understood that the slight variations in the shape of the protrusions, particularly adjacent the vertices and/or between the convex and tail portions will not significantly affect the operation of the invention, provided that fluid passing over the surface of a symmetrical portion is first accelerated in passing over the arcuate portion and then enabled to continue at the higher velocity, thereby further reducing the pressure above the first fluid accelerating surface and enhancing the tendency of the fluid to continue flowing in a controlled manner and without causing undesirable turbulence such as the turbulent flow associated with the stalling of an aircraft wing and the resulting excessive drag. It is preferred that the widest section extending between the outer surfaces of the two convex arcuate portions is positioned at about one third the distance from the vertex nearest the leading edge of the aerofoil to the vertex nearest the trailing edge of the aerofoil.

Preferably, the protruding pieces have a surface substantially parallel to the fluid accelerating surface which is shaped to follow the contour of the fluid accelerating surface or otherwise to provide a contour that mirrors or enhances the aerodynamic lifting effect of the fluid accelerating surface. Preferably, the depth of the protruding

piece or pieces does not extend significantly beyond the boundary layer of the aerofoil when the aerofoil is in motion.

The protruding piece or pieces may be permanently fixed to the aerofoil or may be extendable and retractable from beneath the fluid accelerating surface of the aerofoil. The extension and/or retraction of the protruding piece or pieces may optionally be effected by the operation of devices such as a leading or trailing edge flap or slat of the aerofoil. The protruding piece or pieces may, optionally, extend substantially entirely across the chord of the aerofoil. Alternatively, they may extend only partially across the chord of the aerofoil. Optionally, the pieces will be a fraction of the length of the chord and will be positioned adjacent the leading edge and/or the trailing edge of the aerofoil. The fraction may be less than about one tenth the length of the chord.

Preferably the aerofoil is provided with a plurality of the protruding pieces. Preferably, the plurality of pieces are spaced substantially equi-distant from one another along the length of the aerofoil. Where only one protruding piece is provided, in some applications it may be advantageous that this be positioned towards the end of an aerofoil, such as near to the tip of an aircraft wing.

The inventors have found that by providing one or more protrusions to the fluid accelerating surface of an aerofoil as described in accordance with the invention, fluid passing over the fluid accelerating surface is accelerated to a higher velocity than with the conventional aerofoil, thereby creating greater lift in an aerofoil of comparable dimensions. It is postulated that the aerodynamic symmetrical surfaces of the protruding pieces further reduce the pressure of the fluid passing over the fluid accelerating surface of the aerofoil and enhancing the adhesion of the boundary layer so as to minimise turbulence and consequent drag resulting at the trailing edge of the aerofoil. Furthermore, wind tunnel tests on aircraft wings making use of the present invention have exhibited enhanced lift over comparatively proportioned conventional aerofoils particularly when presented at angles of attack greater than about 13° and have produced encouraging results at angles of attack up to around 19°-23°.

Practical applications of the invention are wide spread and may include, without limitation, use in aircraft wings, boat propellers, windmills and high speed land vehicles. Other applications may arise in turbines such as steam and water turbines, or compressor and/or driven turbines in jet engines. In the particular case of aircraft wings it is envisaged that the invention will permit slower and safer landing of aircraft, reducing the incidence of stalling on the wing. In other applications, expected benefits include more efficient power generation in windmills and vehicle propellers which can be operated at greater angles of attack and at greater speeds without cavitation problems.

An embodiment of the invention will now be further described by way of example with reference to the following Figures in which;

Figure 1 illustrates schematically an aircraft wing embodying the invention (a) in a plan view across the span of the wing, and b) in a section chord-wise through the wing.

Figure 2 Shows graphically data recorded in a wind tunnel for the embodiment illustrated in Figure 1 and a conventional aerofoil wing of comparable dimensions.

As can be seen from Figure 1the aircraft wing comprises a main body 1 which is essentially an aerofoil in cross section. The wing has a leading edge 2 and a trailing edge 3. Equi-spaced along the upper surface of the wing are a plurality of protruding pieces 4. Each piece 4 is substantially symmetrically shaped about a line parallel to the chord of the wing. Each piece 4 comprises two distinct portions, a symmetrically convex portion 5 and a flatter, tapering tail portion 6. From Figure 1(b) it can be seen that the protrusions have a top surface 7 which generally follows the profile of the upper surface of the main body of the wing.

In use, air passing over the top surface of the main body 1 is firstly accelerated by passing over the convex surface of the aerofoil, the air passing the convex surfaces of the convex portion 5 of the protruding pieces 4 is further accelerated relative to air

passing in a relatively straight line between the protruding pieces. Further accelerations and reductions in pressure may be brought about by a Bernoulli effect occurring between adjacent pairs of protruding pieces. As previously described, the higher velocity of the air passing over the upper surface of the wing results in a further reduction in pressure immediately above that surface and a consequential increase in the lifting force caused by the pressure differential that also serves to increase the adhesion of the conventional fluid flow over the fluid accelerating surfaces.

Figure 2 illustrates graphically the drag and lifting forces occurring over a range of angles of attack for conventional aerofoil shaped wing and the same wing modified to incorporate protruding pieces in accordance with the present invention. A table of the results plotted in the graph is summarised below.

Angle of Attack	**Modified Lift (Relative)**	**Normal Lift (Relative)**	**Modified Drag (Relative)**	**Normal Drag (Relative)**
3	4.795	5.095	1.025	0.605
7	9.58	9.42	1.64	1.04
11	13.301	12.988	2.66	1.1
15	17.065	16.725	4.308	2.07
19	18.512	13.922	6.069	4.307
23	18.132	12.586	7.617	5.067

As can be seen compared to the conventional wing, lifting forces on the modified wing are somewhat higher and are accompanied by marginally higher drag forces at lower angles of attack up to about 15° , however, above that level the lifting force exhibited by the conventional wing begins to drop faster and the drag force rapidly increases. With the modified wing, the drag force continues to rise slowly at a steady rate whilst the lifting force continues to rise at a significant rate. As can be seen, the lifting force of the modified wing begins to plateau at around 23° but remains

within workable limits up to that point.

It is to be understood that the foregoing represents just one embodiment of the invention, other embodiments of which may occur to the skilled addressee without departing from the true scope of the invention as claimed in the appended claims.

CLAIMS

1. An aerodynamic device comprising an aerofoil having a first fluid accelerating surface and an opposing second surface, a leading edge facing the direction of motion of the aerofoil and a trailing edge opposing the leading edge, the first fluid accelerating surface having positioned thereon one or more protruding pieces, the pieces being characterised by a shape comprising, two opposing substantially symmetrical portions adjoined at two vertices about a line of symmetry extending between the vertices and chord-wise of the aerofoil, each symmetrical portion comprising a substantially convex arcuate portion towards the leading edge of the aerofoil and an extending, flatter tail portion towards the trailing edge of the aerofoil.

2. An aerodynamic device as claimed in claim 1 wherein the widest section extending between the outer surfaces of the two convex arcuate portions is positioned at about one third the distance from the vertex nearest the leading edge of the aerofoil to the vertex nearest the trailing edge of the aerofoil.

3. An aerodynamic device as claimed in claim 1 or claim 2 wherein the protruding piece or pieces have a surface parallel to the fluid accelerating surface of the aerofoil which is shaped to follow or blend with the contour of the fluid accelerating surface.

4. An aerodynamic device as claimed in any preceding claim wherein the depth of the protruding piece or pieces does not extend significantly beyond the boundary layer of the aerofoil when the aerofoil is in motion.

5. An aerodynamic device as claimed in any preceding claim wherein the protruding piece or pieces are permanently fixed to the aerofoil.

6. An aerodynamic device as claimed in any one of claims 1 to 4 wherein the

protruding pieces are extendable and retractable from beneath the fluid accelerating surface of the aerofoil.

7. An aerodynamic device as claimed in claim 6 wherein the extension and/or retraction of the protruding pieces is effected by the operation of devices such as a leading or trailing edge flap or slat of the aerofoil.

8. An aerodynamic device as claimed in any preceding claim wherein the protruding piece or pieces extend substantially entirely across the chord of the aerofoil.

9. An aerodynamic device as claimed in any preceding claim wherein the protruding piece or pieces extend partially across the chord of the aerofoil.

10. An aerodynamic device as claimed in claim 8 wherein the protruding piece or pieces are greater than about one tenth of the length of the chord of the aerofoil.

11. An aerodynamic device as claimed in any preceding claim wherein the protruding piece or pieces are positioned adjacent the leading edge and/or trailing edge of the aerofoil.

12. An aerodynamic device as claimed in claim 11 wherein the pieces are less than about one tenth the length of the chord of the aerofoil.

13. An aerodynamic device as claimed in any preceding claim wherein there are a plurality of protruding pieces and the pieces are substantially equi-spaced along the length of the aerofoil.

14. An aerodynamic device as claimed in any preceding claim wherein a protruding piece is positioned at or adjacent to one end of the aerofoil.

15. An aerodynamic device as claimed in any preceding claim wherein the aerofoil

is present against the fluid at an angle of attack greater than about 13° .

16. An aerodynamic device as claimed in claim 15 wherein the angle of attack is greater than about 17°.

17. An aerodynamic device as claimed in any preceding claim wherein the device is an aircraft wing.

18. An aerodynamic device as claimed in any of claims 1 to 16 wherein the device is a propeller.

19. An aerodynamic device as claimed in claim 18 wherein the propeller is a boat propeller.

20. An aerodynamic device as claimed in claim 18 wherein the propeller generates power in a windmill or watermill.

21. An aircraft comprising an aerodynamic device as claimed in any one of claims 1 to 18.

22. A boat comprising an aerodynamic device as claimed in claim 18 or 19.

23. A windmill comprising an aerodynamic device as claimed in claim18 or 20.

24. A helicopter or other aircraft comprising an aerodynamic device as claimed in claim 18.

25. A turbine comprising an aerodynamic device as claimed in any one of claims 1 to 18.

26. An aerodynamic device substantially as described herein and with reference to the Figures 1 and 2.

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Application No: GB 0031163.9 **Examiner:** Brian A Woods
Claims searched: 1-25 **Date of search:** 8 August 2002

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Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): B7W(WWJB); F1V(VCVV); F2R(RD);

Int Cl (Ed.7): B63H1/26; B64C(3/58,11/18,21/00,23/00,23/06,27/467); F01D5/14; F03B(3/12,3/18); F03D1/06; F15D(1/10,1/12);

Other: On-Line: WPI; EPODOC; PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X : Y	GB 2175351 A	(OPEN) See figs 1-4, noting movable aerofoil 16.	X: 1,2,8, 11,14,15, 16,17,18, 19,20,23 Y : 6
X : Y	EP 0082378 A2	(STICHTING) See figs 1-5 noting aerofoils 2 & 3 and 12 & 13.	X : 1 at least Y : 6
X : Y	EP 0018114 A1	(U.K GOVERNMENT) See fig 5 & 6 noting aerofoil 14 & 15.	X : 1,2,5, 8,10,17, 18, 21,24 Y : 6
X : Y	US 6042059 A	(CONTINUUM) See fig 1 and 7-15, noting tabs 20,22,24,26.	X: 1,2,9, 10,14,17, 21 Y:6

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		

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Application No: GB 0031163.9

Claims searched: 1-25

Examiner: Brian A Woods

Date of search: 8 August 2002

Category	Identity of document and relevant passage		Relevant to claims
X: Y	US 4017041 A	(NELSON) See figs 6,7,8,9 & 10, noting aerofoils 2,3,4 and velocity/angle of attack diagrams.	X : 1,2,5, 8,14,15, 16,17,21 Y : 6
X : Y	US 3960345 A	(GRUMMAN) See fig 4, noting aerofoil 16 and shaped fuel tanks, 44.	X : 1 at least. Y : 6
Y	US 2885161	(DOUGLAS) See fig 4 noting retractable fin 16.	6
X : Y	US 1724110 A	(REID) See figs 1-12, noting protrusions.	X : 1,2,5, 8,9,10,11, 14, 17,21 Y : 6

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.